Quarterly Report No. 1

King County
Fuel Cell Demonstration Project

Quarters 2 and 3, 2004

Prepared for

US EPA

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Prepared by

King County

Seattle, WA

and

CH2MHILL

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Table of Contents

Background

This Quarterly Report for the King County Fuel Cell Demonstration Project is intended to provide information regarding the experience gained from the operation of the fuel cell as well as performance data. The Quarterly Reports will be submitted throughout the two-year demonstration period, April 2004 – April 2006. The demonstration period has two objectives:

(1) That molten carbonate fuel cell technology can be adapted to use anaerobic digester gas as a fuel source; and
(2) That a nominal plant power output target of 1 MW (net A.C.) can be achieved using either digester gas or natural gas/scrubbed digester gas.

The participants in this project are:

- King County
- FuelCell Energy Inc.
- U.S. Environmental Protection Agency (EPA)
- CH2M HILL
- Brown and Caldwell
- Hawk Mechanical

In cooperation with the U.S. Environmental Protection Agency (US EPA) and FuelCell Energy Inc., King County is sponsoring the world's largest demonstration project of a molten carbonate fuel cell (MCFC) (1 mega watt (MW)) using digester gas. CH2M Hill and Brown and Caldwell are assisting King County in the coordination and management of the overall project. CH2M HILL and Brown and Caldwell have direct responsibility for monitoring and reporting of project status, design and utility interface requirements, assistance during construction, start-up, testing, and operation, and analysis and reporting of the results of the demonstration project.

Municipal wastewater treatment plants that treat wastewater produce solids, which are typically treated through anaerobic digestion and produce large quantities of gas that is about 60% methane (CH_4) and 40% carbon dioxide (CO_2). Currently, most small plants simply burn the gas in a flare. Larger plants more frequently reuse the combined gases on site for heat or power, or remove the CO_2 and sell the remaining gas. Using a MCFCs eliminate CO_2 removal costs and make more efficient use of gas resources while generating electricity.

The King County demonstration plant is sized to produce 1 MW of power. A significant portion of the waste heat from the fuel cell power plant exhaust will be integrated into the existing heat distribution system offering further efficiency.MCFC is one of the most efficient of the fuel cell technologies under development. Fuel cells produce electric power directly through electrochemical reactions using air and fuels such as natural gas, landfill gas, and anaerobic digester gas. By avoiding the two step process of conventional combustion technology, where fuel is first burned and then heat is used to produce power, fuel cells are most energy efficient, better for the environment, quieter, and ultimately more cost effective.

Review of Fuel Cell Performance

Reports will be prepared for EPA quarterly, beginning with Quarter 2 of 2004, which is the quarter when the fuel cell began operation. This report covers Quarter 2 (Q2-04) and Quarter 3 (Q3-04), 2004.

Q2-04 and Q3-04 marked important milestones for the Fuel Cell Demonstration Project. The fuel cell operated at 100% power on both natural gas and digester gas. Emissions testing was performed and showed compliance with the California Air Resources Board Certification (CARB) certification for distributed generation for year 2007 was successful.

Description of Three Gas Supplies

There are three gas supplies to the fuel cell:

- **Gas 1 =** Natural Gas from King County (KC) – Anaerobic digester gas from KC that has been scrubbed on-site to "pipeline quality" natural gas
- **Gas 2 =** Natural Gas from Puget Sound Energy (PSE) – Natural gas supplied by the local gas utility, PSE
- **Gas 3 =** Raw Digester Gas – unscrubbed anaerobic digester gas from the digester gas scrubber header

Potential Gas 3 Supply Changes

Consideration has been given to relocate the unscrubbed gas supply (Gas 3), directly from the digesters instead of from the scrubber header as in Gas 3. When the scrubbed digester gas does not meet the specified PSE methane content, the scrubbed gas is diverted back to the gas header upstream of the scrubbers and ultimately is sent to the flares when sufficient pressure has been reached. The divert events cause the methane content of the unscrubbed digester gas in the header to increase abruptly. This rapid increase is not easily accommodated by the fuel cell as the change in methane content requires a change in gas flow to supply the same amount of fuel to the fuel cell.

On September 29 King County did a test to see if it was possible to get high methane-content gas into the digester gas line that is used for digester mixing. Methane content for all samples was below 60.5%. It is clear that high methane gas makes it to just upstream of scrubber compressor suction and to the line to fuel cell, and to the line to the boiler. This proves that installing a new gas line that would come directly from the digester mixing lines would maintain a constant methane content even during a divert event. The decision on whether or not the new gas line will be installed will be made upon completion of control logic testing by FCE. This testing is to refine the time it takes to switch from unscrubbed digester gas to natural gas during divert events to ensure a constant gas supply to the fuel cell.

Major Activities During Reporting Period

The first phase of startup testing began with Gas 1 on March 25th and continued until April 19th. Along with monitoring the performance of the fuel cell system, one of the purposes of the testing was to reach stable operation of the fuel cell system for the California Air Resources Board (CARB) emissions certification testing. Operations were stopped on April 19th because of repeated interruption of Gas 1 supply.

In order to solve the problem of Gas 1 supply loss, King County and Puget Sound Energy (PSE) realigned the utility natural gas (Gas 2) so that it could be provided as a back-up to Gas 1. However, the PSE natural gas had high levels of carbonyl sulfide (COS), a compound that if not removed could damage the fuel cell.

As a result, a special copper and aluminum oxide medium to remove COS was installed temporarily in one the two the existing cold gas desulfurizer vessels, which normally uses activated carbon. A new, permanent cold gas desulfurizer vessel dedicated to COS removal is currently being installed. All Gas 1 and 2 will run through the new vessel, which will be upstream and in series with the existing desulfurizers.

The second phase of startup testing with natural gas began on June 11th and continued until June 20th using Gas 1. On June 21st through June 29th, the first phase of CARB emissions testing occurred using Gas 1. The following parameters were measured: nitrogen oxides (NOx), carbon monoxide (CO), and non-methane hydrocarbons (NMHC). The emissions were measured for one hour at 50, 75, and 100% power.

The testing was done in three different phases. The second and third phases were done from July 21st through July 29th. The fuel cell was held at 100% power during this entire time period, including the interim period from June 29th through July 21st when emissions testing was not occurring. The emissions from the fuel cell met the following requirements of CARB 07:

- NOx < 0.07 lb/MW-hr
- CO < 0.1 lb/MW-hr
- NMHC < 0.02 lb/MW-hr

Once the emissions testing was complete, startup testing of the fuel cell continued with natural gas through August 1st.

On August 2nd, FCE began testing with digester gas (Gas 3). The digester gas supply was constant, but the gas quality was not constant. When Gas 1 does not meet PSE specifications, it cannot be sold and is put back into the raw digester gas supply. When this occurs, the methane content of Gas 3 increases from approximately 65% to 85% over a three hour period. The observed changes in fuel composition exceeded limits acceptable for reliable operation of the fuel cell. The gas supply to the fuel cell was switched back to Gas 1 on August 5th while a solution to the Gas 3 quality was investigated.

From August 5th through September 3rd, the fuel cell operated at 1MW on natural gas (Gas 1). There was a two day period in mid-August where the fuel cell operated in hot standby to implement control logic modifications. Hot standby is when the fuel cell is maintained at a ready-to-generate power status at approximately 1200°F. Minimal fuel is used to maintain temperature, but no power is generated. To verify operation on digester gas, a short run was conducted from September 4th through the 12th. During this period the plant operated at 100% power on digester gas, Gas 3. There were various plant trips due to the site's digester gas compressor shut down, and the fuel cell had to be ramped back to 100% power after each trip. On September 13th, the plant was shut down for a planned three week electrical outage, not related to the fuel cell project.

Peer Review Team

King County formed a Peer Review Team (Team) for this project that is comprised of various experts in the energy and wastewater treatment field. The Team meets approximately twice a year to review data and offer guidance to the project team. Upon completion of the demonstration period, members of the Team will review the final report. The first Team meeting was held in November 2003. The second meeting was held on September 21st. The following people are on the Peer Review Team.

Name	**Affiliation**	**Contact Information**	**Attended Sept 2004 Meeting?**
Steve Behrndt	Portland Bureau of Environmental Services, Operations Manager 5001 N. Columbia Blvd. Portland, OR 97203	Tel: 503-823-2432 Steveb@bes.ci.portland.or.us	Yes
Gordon Bloomquist	WSU Energy Program (from OTED Energy Policy Div.). 925 Plum St., Bldg 4 Olympia, WA 98504-3165	360-956-2000 agency line 360-965-2016 direct bloomquistg@energy.wsu.edu	No
William H. Hahn	Science Applications International Corporation (SAIC) 1125 Roger Bacon Dr. Reston, VA 20190	Tel:703-318-4527 Fax:703-318-4538 William.h.hahn@saic.com	Yes
Lory Larson	Southern California Edison 6042 N. Irvindale Ave., Suite B Irvindale, CA 91702	Tel: 626-633-7161 lory.larson@sce.com	Yes
Charles Chamberlain	Co-Director Schatz Energy Research Center Humboldt State University Arcata, CA 95521-8299	Tel:(707) 826-4345 Fax:(707) 826-4347 FAX cec2@humboldt.edu	Yes
Ron Spiegel	Environmental Protection Agency Cincinnati Research Center US EPA/APPCD/APB, MS E305-2 Research Triangle Park, NC	Tel: 919-541-7542 Spiegel.ronald@EPA.gov	Yes

Name	**Affiliation**	**Contact Information**	**Attended Sept 2004 Meeting?**
	27711		
Steve Van Slyke	Puget Sound Clean Air Agency 110 Union St., Suite 500 Seattle, WA 98101	Tel: 206-689-4052 stevev@pscleanair.org	Yes
Kristen Patneaude	Massachusetts Water Resources Authority Deer Island Treatment Plant P.O. Box 100 Winthrop, MA 02152	Tel: 617-660-7871 Fax: 617-660-7956 Kristen.Patneaude@mwra.state.ma.us	No
Dick Finger	King County West Point Treatment Plant 1400 Utah Street West Seattle, WA 98199	Tel: (206) 263-3825 Dick.finger@metrokc.gov	Yes
Mike Fischer	King County South Treatment Plant 1200 Monster Road SW Renton, WA 98055	Tel: (206) 684-2400 mike.fischer@metrokc.gov	Yes
Carol Nelson	King County South Treatment Plant 1200 Monster Road SW Renton, WA 98055	(206) 684-2466 carol.nelson@metrokc.gov	Yes
Greg Bush	King County Planning and Compliance Group 210 S. Jackson Street, 5th Floor Seattle, WA 98109	(206) 684-1164 greg.bush@metrokc.gov	Yes
John Spencer	CH2M HILL 777 108th Ave NE, Suite 800 Bellevue, WA 98004	425-233-3468 jspence1@ch2m.com	Yes
Eleanor Allen	CH2M HILL 777 108th Ave NE, Suite 800 Bellevue, WA 98004	425-233-3441 eallen@ch2m.com	Yes
Jaimie Hennessy	CH2M HILL 777 108th Ave NE, Suite 800 Bellevue, WA 98004	425-233-3343 Jhenness@ch2m.com	Yes
Dan Rastler	EPRI Technical Leader, Distributed Energy Resources Program Palo Alto, CA	(650) 855-2521 drastler@epri.com	No
David Hennessy	FuelCell Energy 3 Great Pasture Road Danbury, CT 06813	(203) 825-6484 dhennessy@fce.com	Yes

Name	Affiliation	Contact Information	Attended Sept 2004 Meeting?
Dan Beachy	FuelCell Energy 3 Great Pasture Road Danbury, CT 06813	(203) 203-205-2457 dbeachy@fce.com	Yes
Stephen Torres	FuelCell Energy 225 South Lake Avenue Suite 300 Pasadena, CA 91101	Tel: 626-432-5410 Storres@fce.com	Yes

Efficiency Calculations

Efficiency will be calculated in seven ways as shown in Table 1. The basic efficiency reported for the power plant on natural gas includes plant parasitic power as well as the DC to AC conversion losses. Calculations show an efficiency of 43% while operating on natural gas (Measurement 1), 44% while operating on digester gas and including the digester gas skid loads (Measurement 2), and 46% without those loads (Measurement 3).

Table 1 - Efficiency Measurements

Efficiency Measurement	Components	Where Calculated on Flow Chart	How Calculated
1	Power plant system on natural gas	C/A	Electricity out /Total fuel in (natural gas)
2	Power plant system on digester gas	C/(A+B)	Electricity out /Total fuel in (natural gas for pilot light + digester gas)
3	Power plant system on digester gas (with digester gas skid losses)	(C+F)/(A+B)	(Electricity out +power used for skid)/Total fuel in (natural gas for pilot light + digester gas)
4	Fuel stack only	G/I	Measurement method to be determined
5	With heat recovery on natural gas	(C+D)/A	(Electricity out + heat energy recovered)/Total fuel in (natural gas)
6	With heat recovery on digester gas	(C +D)/(A+B)	(Electricity out + heat energy recovered)/Total fuel in (natural gas for pilot light + digester gas)
7	With heat recovery on digester gas (with digester gas skid losses)	(C+F+D)/(A+B)	(Electricity out +power used for skid + heat energy recovered)/Total fuel in

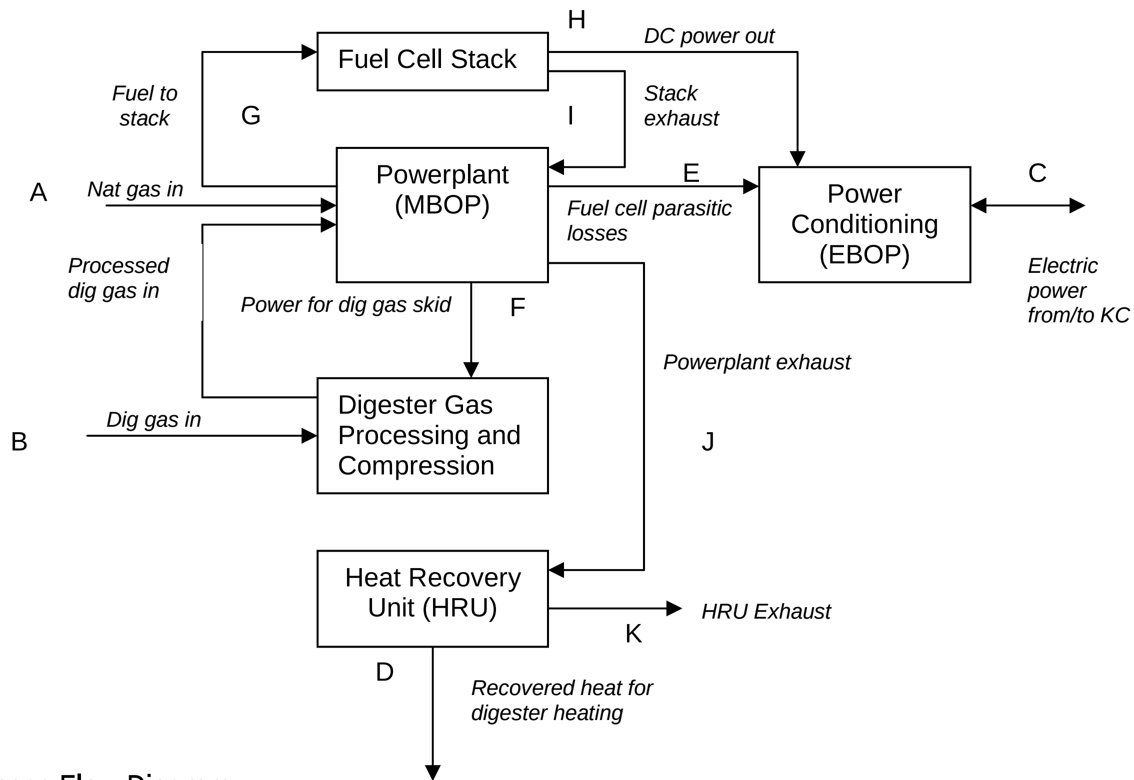


Figure 1 – Process Flow Diagram

Highly accurate efficiency calculations require use of flow meters calibrated to greater accuracy than the fuel cell power plant has. Therefore efficiency numbers will differ depending on the method used to obtain gas flow information and electrical output data. The efficiency calculations presented here have an estimated +/- 2 to 3% variance.

All efficiency calculations are based on the fuel lower heating value (LHV) of 900 BTU/ft3 for natural gas and 548 BTU/ft3 for digester gas. The efficiency calculations are done at full load under standard conditions. Variations in ambient temperature and elevation do impact the fuel cell performance and efficiency. There has been some tuning of equipment on-site to reduce parasitic loads.

The heat recovery unit (HRU) is currently not fully operational. Efficiency Measurements 5, 6 and 7 will be completed once the HRU is in operation.

Operational Summary

One measure of the fuel cell's performance is availability, or the percentage of time the fuel cell operates relative to the amount of time it is available to operate. For the two quarters analyzed in this report, the operation time was evaluated from June 14th through August 31st. Previous to June 14th, there was not a consistent supply of natural gas, so that timeframe was not incorporated into the analysis.

During Q2-04 and Q3-04, the fuel cell operated 93.5% of the time it was available to operate. The 6.5% of the time it had forced outages included 4 emergency plant shutdowns and delays in restarting after planned outages. The times it was unavailable to operate were from planned KC electrical outages, hot standby testing of digester gas, and various planned electrical trips from the test plan.

Additional measures of the fuel cell's performance are summarized in Table 2 and Table 3. Table 1 is for natural gas and Table 2 is for digester gas.

Table 2 - Fuel Cell Operational Summary on Natural Gas (June 14 – Sept. 3, 2004)

Year	**2004**		**2005**				**2006**	
Parameter	**Q2 andQ3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**
Run time (hours)	1,897							
Power generated (kWh)	1.4M kWh							
Availability	93%							
Shutdown	7%							
Efficiency	43%							

Table 3 - Fuel Cell Operational Summary on Digester Gas (Sept. 4 – 12, 2004)

Year	**2004**		**2005**				**2006**	
Parameter	**Q2 andQ3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**
Run time (hours)	313							
Power generated (kWh)	78,664							
Availability	64%							
Shutdown	35%							

Year	2004		2005				2006	
Efficiency	44%							

Performance of Power Plant Components

This section describes the performance of each of the individual components in the fuel cell power plant.

King County Scrubbed Digester Gas Treatment System (Gas 1)

The compressors in th Binax gas scrubbing system repeatedly failed to maintain adequate gas treatment causing the natural gas produced to be below the specified value for sale to PSE and causing it to be diverted to the anaerobic digester gas (ADG) header and subsequently, when a sufficient pressure has been reached, to the flares. The divert events cause the methane content of the unscrubbed digester gas to increase abruptly. This rapid increase is not easily accommodated by the fuel cell as the change in methane content requires a rapid change in gas flow to supply the same amount of fuel to the fuel cell.

Natural Gas Treatment System (Gas 2)

The supply stream for the Gas 1 natural gas treatment system is being modified to allow for removal of COS that is in Gas 2. As an interim measure ,the fuel cell natural gas treatment system was modified to provide temporary capability to remove COS by replacing one vessel of activated carbon with COS-removal media. There were no other problems with the system; it performed as expected.

Digester Gas Treatment System (Gas 3)

The digester gas treatment system removed the target contaminants during Q2-04 and Q3-04. It did not need to be removed for service or replacement.

Fuel Cell Stack

No problems have been recorded with the fuel cell stack. The results from the emissions testing are shown in Table 4.

Table 4 – Fuel Cell Stack Emission Results

	NOx (ppm)	NOx (lb/MW-hr)	CO (ppm)	CO (lb/MW-hr)	NMHC (ppm)	NMHC (lb/MW-hr)
50% Power	0.22	0.064	5.30	0.126	0.50	0.0048
75% Power	1.64	0.006	4.50	0.075	0.20	0.0014
100% Power	0.22	0.006	6.70	0.104	0.60	0.0038

Heat Recovery System

The heat recovery system was not in operation during these two quarters. Plans are to start testing and operation in the next quarter.

Electrical Balance of Plant (EBOP)

No problems have been recorded with the EBOP.

Maintenance Items

Maintenance of the fuel cell power plant was scheduled during the planned three week shutdown starting September 13th. During this shutdown, normally scheduled preventative maintenance tasks were completed. In addition, several improvements to the plant were completed including:

- Addition of platforms and ladders for improved and safe access.
- Addition of water booster pump for potable (C2) water for gas humidification.
- Control and logic modifications needed to incorporate capability of managing plant response to gas diverts and changes in methane concentrations.
- Repairs related to a gasket leak at the fuel gas deoxidizer flange.
- Improvements to prevent fouling of the unscrubbed digester gas compressor. The strainers in the water line fouled with grease. The water source was C3 water, or chlorinated secondary effluent, that was run intermittently. The solution was to run the water continuously and fouling was no longer a problem.

Performance Metrics

Seventeen performance metrics were established with King County and FuelCell Energy. They are described below in Table 5, with the results from Q2-04 and Q3-04.

Table 5 – Performance Goals and Metrics

Performance Goal	Metric	Q2-04 and Q3-04 Result
1. Deliver high quality and quantity gas to the fuel cell	Acceptable gas supply >95% of the time. Digester gas BTU content between 550 and 610 BTU/scf @ 4 to 7 in w.c.; 50 to 100°F	NG quality and quantity acceptable after 6/14/04. DG BTU/methane content at times too high due to divert events returning NG to ADG header.
2. Produce energy as designed on natural gas and digester gas	Produce 15,000 MWhrs gross power for 2-year test period. Prorate to later half of test after plant normalized after first 6-9 months. 1 MW net. Parasitic electric loads for natural gas and digester gas to be measured during testing. Full power = 140 scfm natural gas	1,450 MWhrs after first 6 months of installation 1 MW net produced on NG and DG
3. Produce minimal noise and equipment interferences	60 dBA at a distance of 100 feet from fuel cell pad (70 dBA at a distance of 10 feet)	Not tested
4. Produce energy at a minimal cost	0.2 full time equivalents (FTEs) – Operations 0.2 FTEs – Maintenance 0.1 FTEs – Miscellaneous Cost of energy to produce 1 kWh of power < \$0.10 (energy off the grid \$0.05, but a premium is paid for green power)	Not applicable to first 6 months of plant normalization
5. Produce minimal air emissions – natural gas and digester gas (LSG/ADG[1])	CO < 10 ppmV NOx < 2 ppmV NMHC < 1 ppmV	Results on Natural Gas: CO=6.7 ppmV NOx=0.22 ppmV NMHC=0.60 ppmV Digester results to be measured at a later date
6. Produce wastewater/drain	Water treatment system brine Cooling water	Not tested

Performance Goal	Metric	Q2-04 and Q3-04 Result
water with no adverse impacts to the treatment plant	Condensate	
7. Operate fuel cell on a continuous basis	Downtime for maintenance and troubleshooting limited to 20 hours/week (remain at hot standby condition) Availability of > 80% Run 85% of the time at full net power for 2 years. Determine frequency of downtime and length of time out of service	93.5% availability. Maintenance and troubleshooting not applicable to first 6 months of plant normalization.
8. Operate fuel cell efficiently	45.0% efficiency on natural gas 45.0% efficiency on digester gas	43% on natural gas (not optimized due to fuel supply issues)
9. Manage system with ease remotely	Monitor and control system through SCADA at the operations building at FCE's office in Danbury, CT	Acceptable
10. Remove hydrogen sulfide effectively from digester gas	Remove hydrogen sulfide to < 10 ppmV on inlet gas	Not tested
11. Reasonable costs to dispose of solid waste	SulfaTreat system lasts for 0.6 years before replacement Carbon systems (both natural gas and digester gas systems) last for 0.3 years before replacement Fuel cell lasts for 3 years before replacement Preconverter catalyst lasts for 5 years before replacement Oxidizer catalyst lasts for 5 years before replacement Exhaust gas polisher lasts for 5 years before replacement Deoxidizer catalyst lasts for 5 years before replacement Fuel cell not negatively affected by digester gas Deactivated catalysts (from preconverter, oxidizer, deoxidizer and exhaust gas polisher) (recover precious metals) Fuel cell stack Desulfurizer (SulfaTreat, activated carbon, CNG-1, CNG-2) Digester gas polisher	Not applicable to first 6 months of plant normalization
12. Recover heat	Recover 1.4MM Btu /hr of heat	Heat recovery not in

Performance Goal	Metric	Q2-04 and Q3-04 Result
successfully	(13,800 lbs gas/hr) 650°F out of stack	operation
13. Achieve output turndown	25% to 100%	Stable operation demonstrated at power levels ranging form 18% to 100% power on both NG and DG
14. Achieve output ramp rate	0.5 kW/min (cold start)	Complete
15. Meet design service life	10,000 hours (1.15 years)	Approximately 2000 hours after 6 months
16. Able to restart from a trip	Trip recovery to back on load in approximately 10 hours	Demonstrated on 7/30: approx. 8.5 hours
17. Able to quickly start	Hot start in 10 hours (standby to rated output)	Demonstrated on 8/7 and 8/20: approx. 9 hours each

[1] Digester gas = LSG =ADG = Low pressure sludge gas = anaerobic digester gas

Lessons Learned

As the King County Fuel Cell Demonstration Project has only recently begun, there is little significant operational or performance data available. Completion of planned training modules may help to alleviate some concerns from operations and maintenance about the "complexity" of the equipment and control systems. However, the fuel cell and its ancillary components do operate and produce consistent power, with low emissions, when provided with a reliable gas supply.

Field Experiences

Several "lessons learned" were experienced in the field during the construction and start-up phase.

Gas Supply

One important challenge has been the supply and quality of fuel at the facility, a problem exacerbated by King County's unique arrangement with its local gas utility.

Historically, digester gas generated at the wastewater treatment plant has been scrubbed and sold to Puget Sound Energy. When the scrubbed digester gas does not meet the utility's specifications, it is automatically returned to the ADG header. However, when the divert event occurs while the fuel cell stack is operating on ADG, it can cause a rapid spike in the methane concentration of raw digester gas in the ADG header, as the scrubber gas is returned to the header and mixed with the raw digester gas. This creates a gas mixture for the fuel cell with relatively high methane content and a rapid rate of increase. The rapid rate of methane increase in the gas triggers a system shutdown due to safety precautions set-up in the control logic. The actual tolerance of the fuel cell for increases in Btu concentration is not known.

Potential solutions to the problem are a new pipeline directly from the digesters instead of the ADG header or change the control system to switch over the natural gas when the digester gas quality is not adequate. Either solution would only be temporary (until 2005) because when the cogeneration system is in place King County will no longer sell the scrubbed gas to PSE. This means that a divert event where the scrubbed gas is recycled back to the ADG header should no longer occur.

In addition to this internal fuel supply challenge; King County is also concerned about concentrations of carbonyl sulfide (COS) in the natural gas that it receives from PSE. COS occurs naturally in natural gas and is uncommonly concentrated in gas from Canada, the source of the PSE gas sent to the South Treatment Plant. COS can "poison" a fuel cell stack and severely degrade performance. As a result, King County is working to add a third cold gas desulfurizer vessel for the natural gas. This vessel will contain copper oxide and aluminum oxide to remove the COS in the PSE gas before introducing it to the stack. While the new vessel is being constructed the redundant activated carbon bed was emptied and copper and aluminum oxide added. This is temporary measure to ensure that no COS reached the fuel cell.

Interconnection

King County experienced some difficulty and frustration resolving interconnection issues with Puget Sound Energy (PSE). The design team began discussions with PSE early in the project, which was critical to the success of the project. It is likely that this problem is not unique to fuel cells, but an issue that all distributed generation technology may face with local utilities

The fuel cell is not isolated from the PSE grid, requiring coordination with the utility for interconnect. The PSE grid provides a voltage and frequency reference point that is required by the fuel cell when operating in parallel to the grid. The local utility and national interconnection standards require generators operating in parallel to take them off line when the generator observes voltage and frequency deviations in the grid from designed conditions. The fuel cell electrical balance of plant senses when these variations in voltage and frequency in the grid exceed certain thresholds and stops generating power to comply with the utilities safety and interconnection rules.

PSE's interconnect also was required for revenue collection. As various demands are placed upon the PSE grid from end users PSE must ensure there is enough power for all. When the fuel cell is on-line, the rates are lower than what they are when the fuel cell is off so that PSE can keep up with the power demand. The interconnect agreement is the vehicle to establish different rates through revenue class metering.

In addition to PSE, the local electrical inspection authority was also unfamiliar with fuel cells. The local inspector's initial apprehension towards the fuel cell was based on particular knowledge of the National Electrical Code (NEC) that applies specifically to residential fuel cells, not the class of the Direct FuelCell installed. The local inspector maintained that all fuel cells were the same. Other more aggressive states like California have instituted interconnection standards for on-site generation equipment like fuel cells, where manufacturers can pre-certify their equipment against these standards and significantly simplify the interconnection process.

King County's experience points to the larger need for education and training, even among industry professionals. Inexperience and discomfort with unfamiliar technology is a barrier hindering the deployment of distributed resource that will be confronted project-by-project, jurisdiction-by-jurisdiction, until the technology becomes more common. Early and frequent communication with local inspectors and utilities can help smooth the process, as the permitting and interconnection agreements may be complex and/or cumbersome.

Other Challenges

The project team reported unanticipated problems, including the previously mentioned presence of water in the first fuel cell stack power module delivered in July 2003, which necessitated its shipment back to FCE and subsequent replacement as a precaution.

As expected, the lessons learned were not restricted to the fuel cell power plant; issues during installation and constructability of the heat recovery system were also experienced. As stated, these and other issues are typical and expected when installing and starting power generation projects. Other previously noted startup and commissioning issues included a water booster pump was required to maintain sufficient pressure in the water treatment system and the new COS removal vessel. Information and experience from the installation and startup are being used in consideration for the design of future installations.

Due to the startup and commissioning and fuel supply issues, training efforts were postponed, but have now been scheduled to occur in December. This will allow King County staff to assume operations and maintenance responsibility for the plant and its auxiliaries.

Despite the challenges noted above relating to the design, fabrication or installation of the power plant, each of the project participants have responded very well in an effort to make the installation at this site a success. Considering that this pilot project is a “first of it’s kind” power plant, some of the design and fabrication problems experienced by King County are to be expected during demonstration projects. Despite any problems related to the design, fabrication or installation of the power plant, FuelCell Energy Inc. has responded very well to the needs to adapt the equipment to meet site conditions.

Positive Outcomes

The King County Fuel Cell Demonstration project has benefited from positive experiences as well. For example, the modules supplied by FCE were installed and made ready for operation very quickly. Now that the typical start-up hurdles have been passed, the fuel cell is operating well and without major issues. Power production is constant and power quality high. Availability even in light of the additional testing and trials required due to the fuel supply issues and initial operation has been high, making the likelihood of improved availability highly probable. The output of the fuel cell did not need to be derated when operating on digester gas, which would have been required with some other fuel cell technologies.

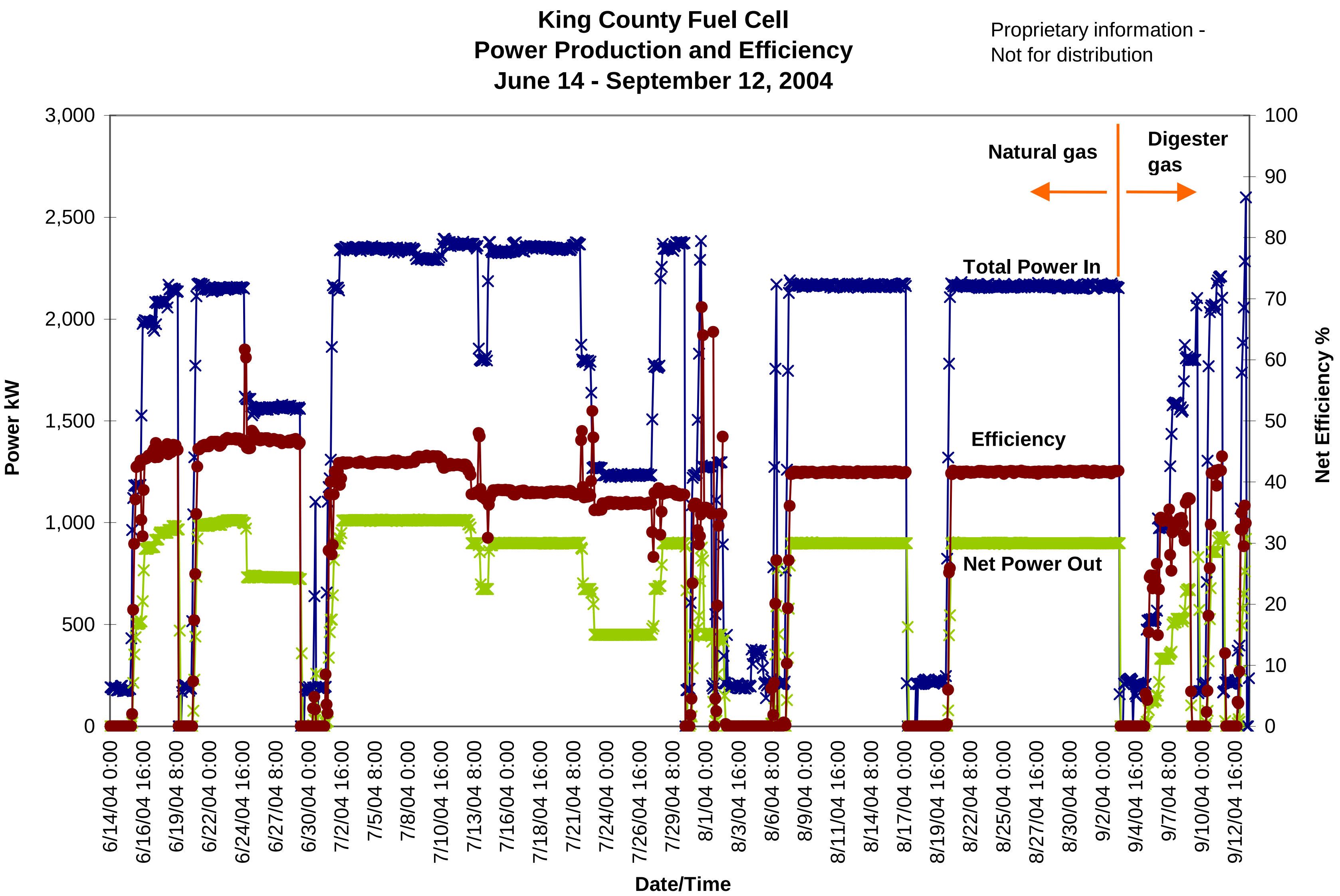
FCE has responded quickly to repair field issues and get the system up and running. From this point forward we will be able to optimize the fuel cell to see what the bookends are for operation parameters. In addition, FuelCell Energy is working to provide controls to provide automatic response to the fuel variations and to switch fuels while running when a fuel divert occurs or when fuel methane concentration exceeds acceptable limits. To date the operators have been cautious, with reason. But now that the stack is operating at steady state the operating parameters can be adjusted and refined.

Appendices

A – ENERGY EFFICIENCY AND OUTPUT DATA

B – GAS FLOW AND METHANE CONTENT

A – ENERGY EFFICIENCY AND OUTPUT DATA



B– GAS FLOW AND METHANE CONTENT